



Advanced 2-micron Solid State Laser Developments

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Acknowledgement

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Supported by Laser Risk Reduction Program



Outline

- Conductively Cooled Amplifier Development
 - Develop technologies for space laser applications
- One Joule Amplifier Testbed
 - Demonstrated a record high energy 2-micron laser
- Tm Fiber Pumped Ho Laser
 - To demonstrate a high efficiency laser technology



Two micron laser amplifier

Objectives:

Develop related laser technologies leading to a conductively cooled, diode-pumped high-energy and high-efficiency 2-micron pulsed laser suitable for space-based remote sensing Lidar applications to support science and exploration missions.

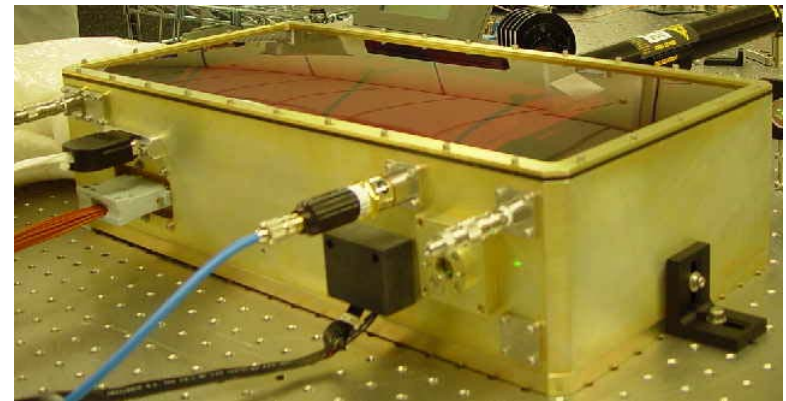
Design Guidance:

- *5 mm DIAMETER LuLiF ROD, 42-43 mm LONG*
- *20 A PACKAGE DIODES, 80 BARS TOTAL*
- *MAX DIODE TEMP: 10 TO 20C*
- *MAX ROD SURFACE TEMP : -80 TO -10C*
- *ROD MOUNTING SURFACE AREA: ~60%*
- *MAX PUMPING SURFACE AREA : ~40%*
- *ALL MATERIALS AND PROCESSES TO BE FLIGHT LIKE*



Conductively cooled oscillator

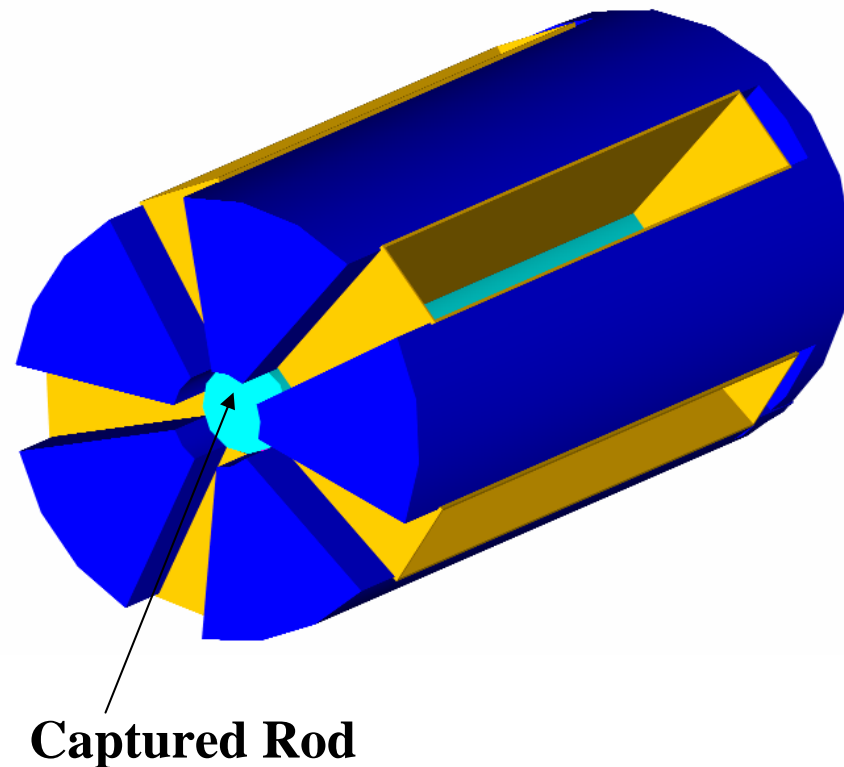
- Established cleanroom and pre-clean room environment for laser system builds
- Free standing, rigid wall, modular, prefabricated 10'x14' clean room Combines clean room performance with high visual appeal, Class 10,000
- Have placed an emphasis on “contamination control” design for last several iterations of the conductively cooled laser systems. (use of lowest outgassing materials, solvents and cleaning procedures, etc.)
- Have successfully developed an 107mJ fully conductive cooled oscillator





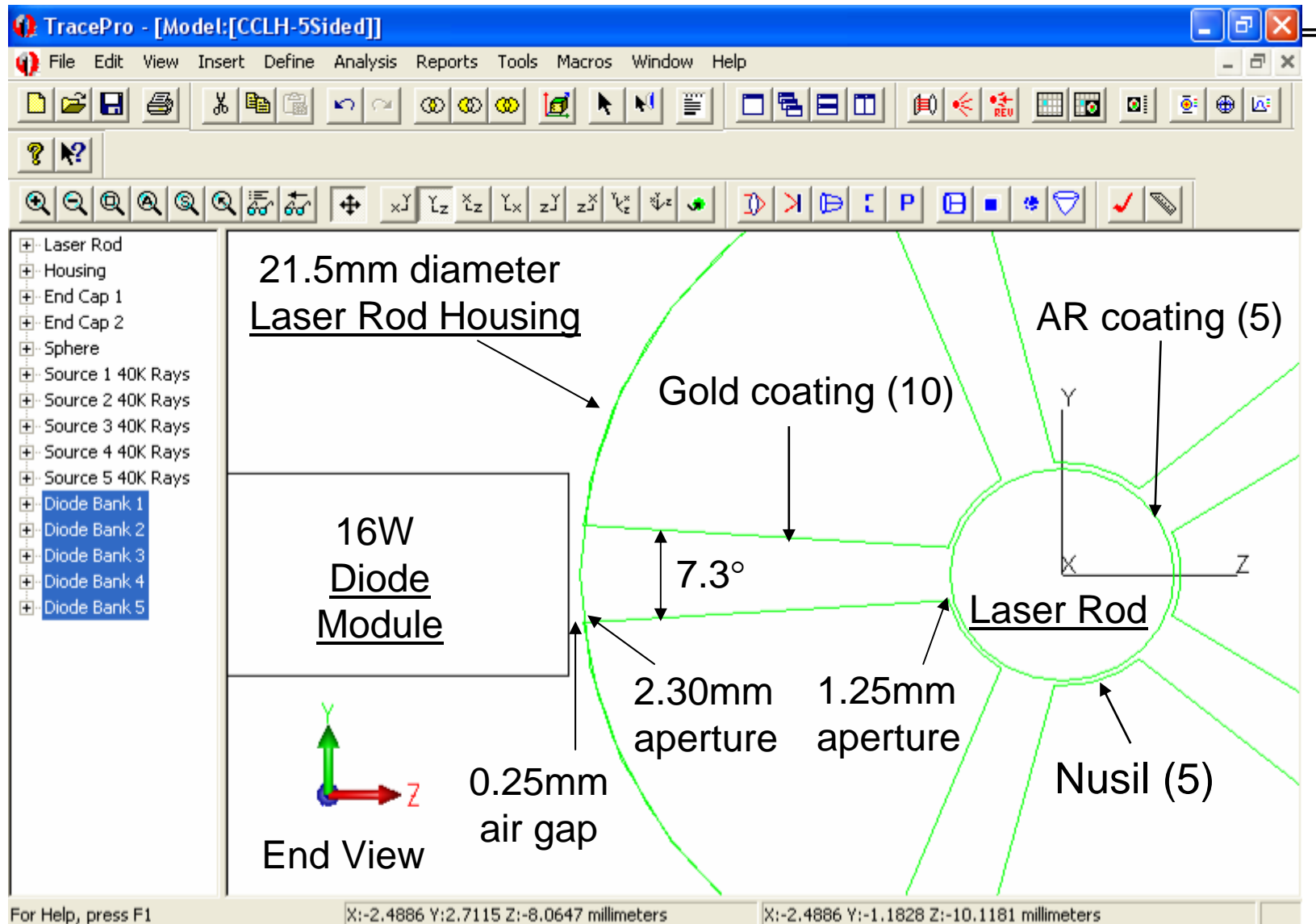
Laser Rod Mount

- CCLH LASER PUMPING SCHEME
- 5-SIDED ILLUMINATION
- 200W TOTAL PRIME POWER
- 4 A DIODE ARRAYS EVERY 72°
- ROD DRY MOUNTED TO CAPSULE HALF
- CAPSULE – THERMOKON 83, COPPER
- ROD CAPTURED BY CAPSULE
- ALL COUPLING MIRRORS EPOXIED IN PLACE





CCLH TracePro Model Detail

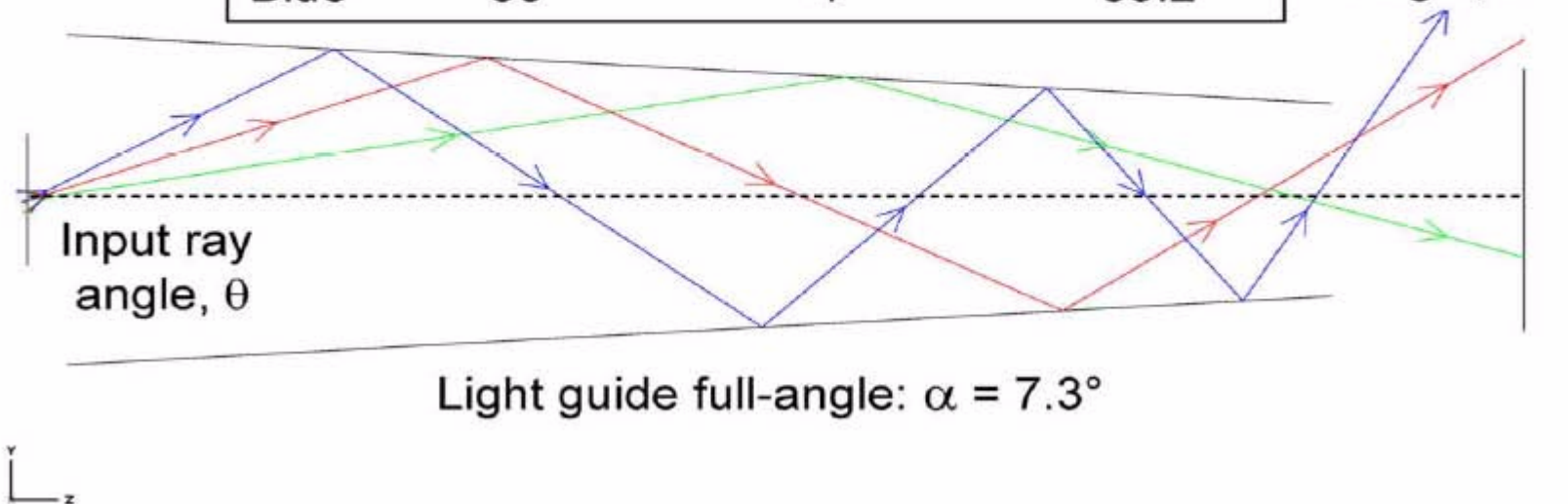




Light Guide

Light Guide Raytrace Example:

	<u>Input \angle</u>	<u># Bounces</u>	<u>Output \angle</u>
Green	10°	1	17.3°
Red	20°	2	34.6°
Blue	30°	4	59.2°



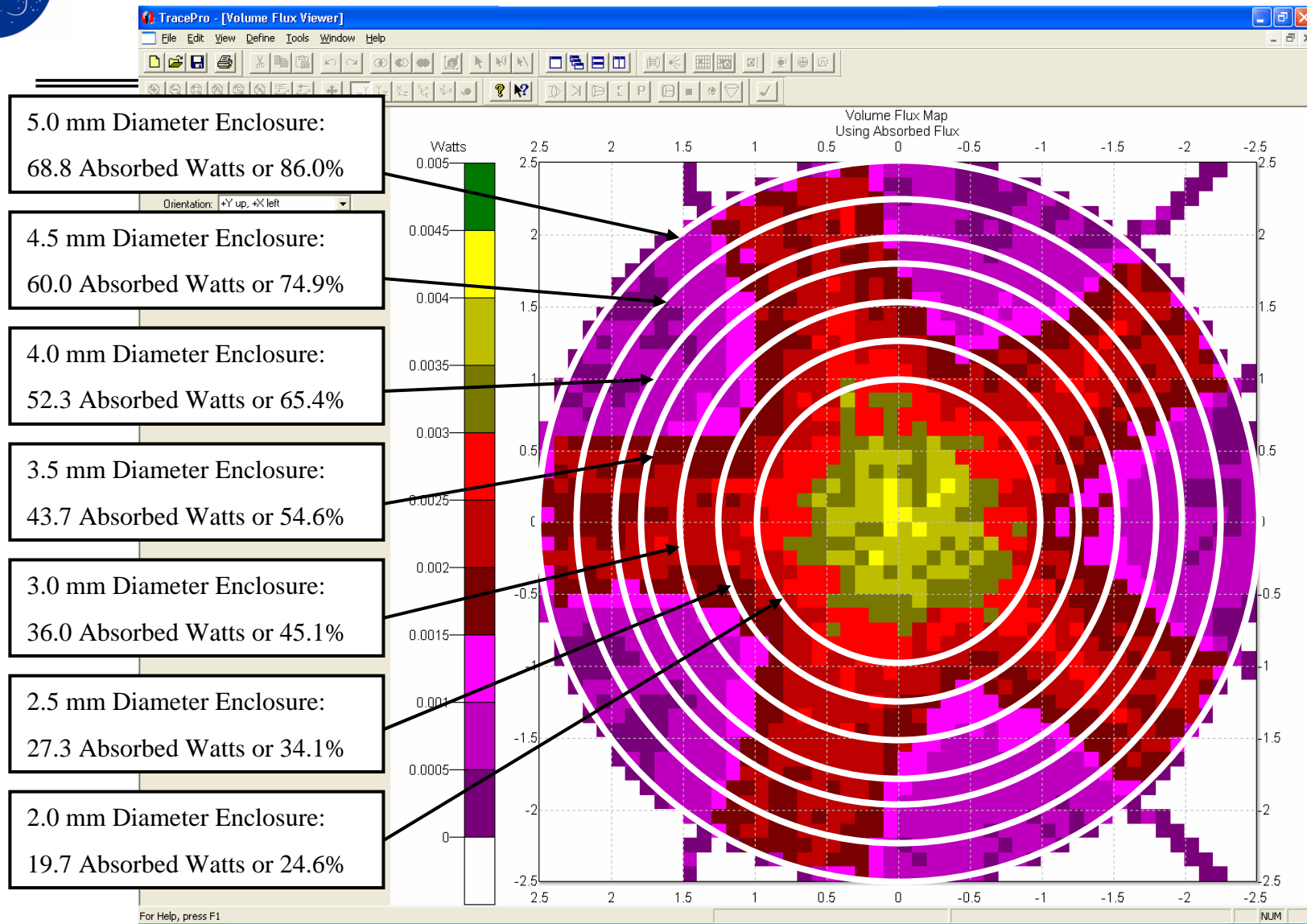


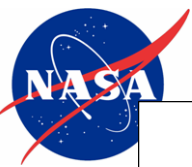
Optical Tasks

- Calculate overall diode array to laser rod coupling efficiency and laser rod absorbed flux distribution using 80W diodes and 5-sided illumination
- Investigate increasing the width of wave-guide aperture by re-allocating cooling arc length percentage to 60/40 and 50/50.
- Optimize diode-pump module coupling optics to increase the laser rod absorbed mode size.
- Analyze the following optical design modifications:
 - Increase the light guide angle
 - Increase the light guide aperture at the laser rod
 - Add holographic diffusers at the light guide exit

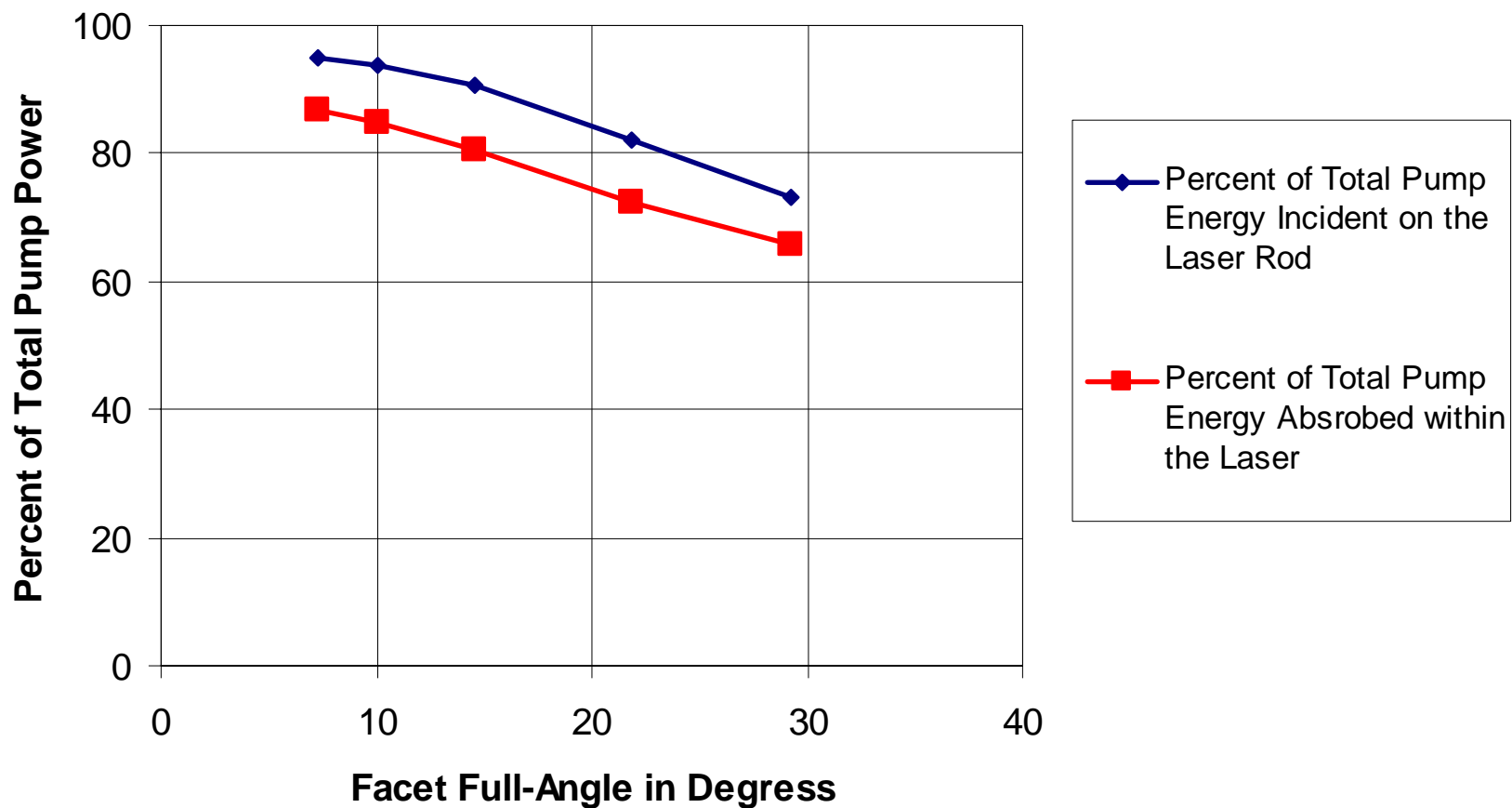


7.3 Degree Facet Full-Angle





Percents of Total Pump Energy Incident on the Laser Rod and Absorbed within the Laser Rod as a function of Facet Full-Angle





Bond Area Effect

Trace Pro File Name (*.oml)	Housing 1	Housing 1B
Optical Design Case	60% Bond Area	50% Bond Area
Total Diode Bar Output (W)	80.00	80.00
Absorbed by Laser Rod (W)	66.52	65.85
	83.2%	82.3%
Absorbed by Rod Housing (W)	4.97	4.37
Reflected/Transmitted to Diodes (W)	8.47	9.75
Escaped Flux (W)	0.03	0.03
Total Flux (W)	79.99	79.99

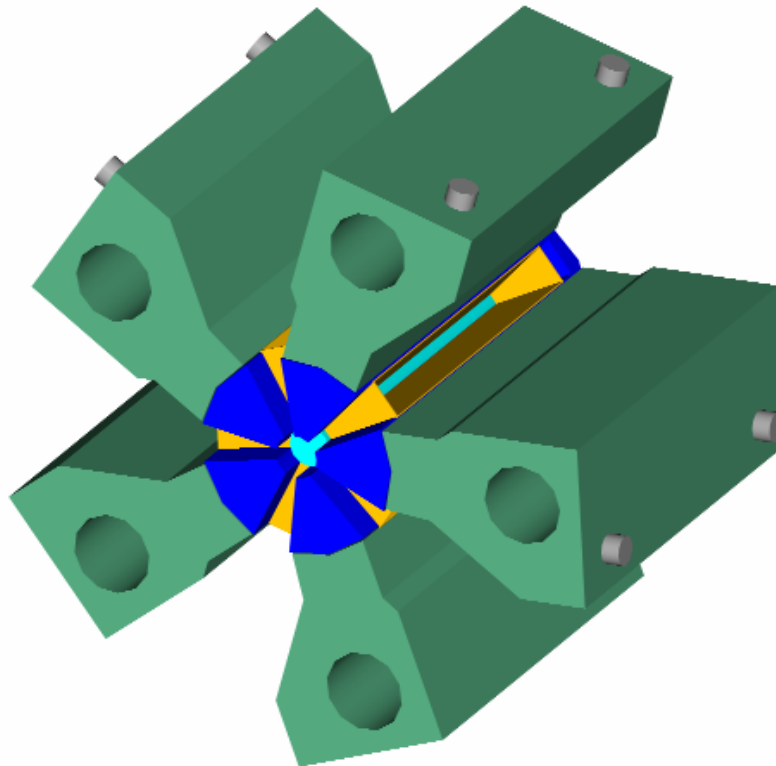


Thermal Tasks

- Investigate the laser amplifier thermal performance using 5mm diameter LuLiF4 rod.
- Compare thermal performance with Thermkon 83 previously used for the oscillator pump and with Copper.
- Compare the thermal performance of a one piece design versus a multi-interfaced laser head.
- Perform analysis to optimize the chiller block for cooling the laser head.



ROD HEAT PIPE MOUNT

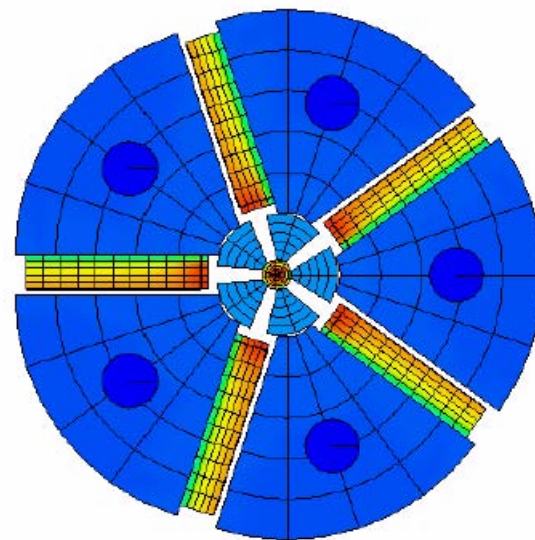
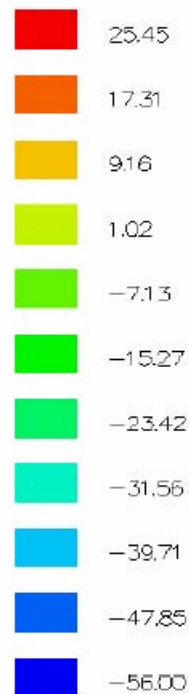
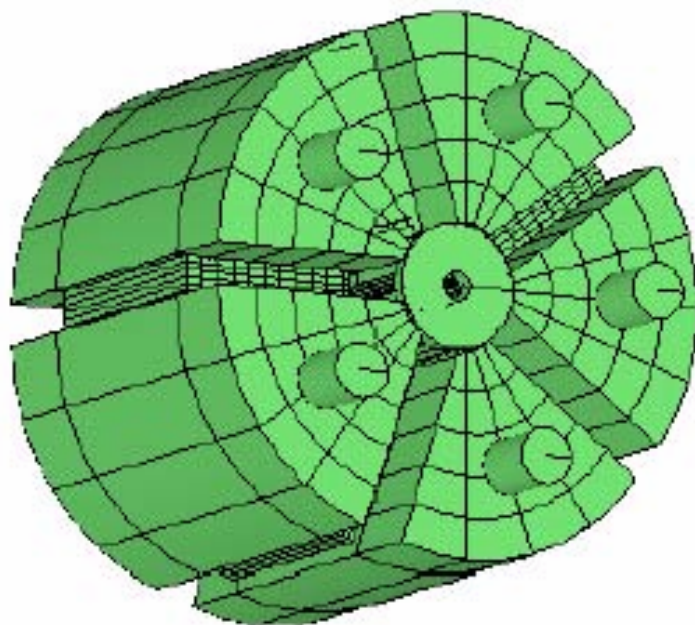


- **ATTACH ROD HEAT PIPE MOUNTS**
- **3/8" HEAT PIPES ARE BASELINED FOR ROD COOLING**
- **HEAT PIPE SADDLES AND CLAMPS – THERMOKON-83**



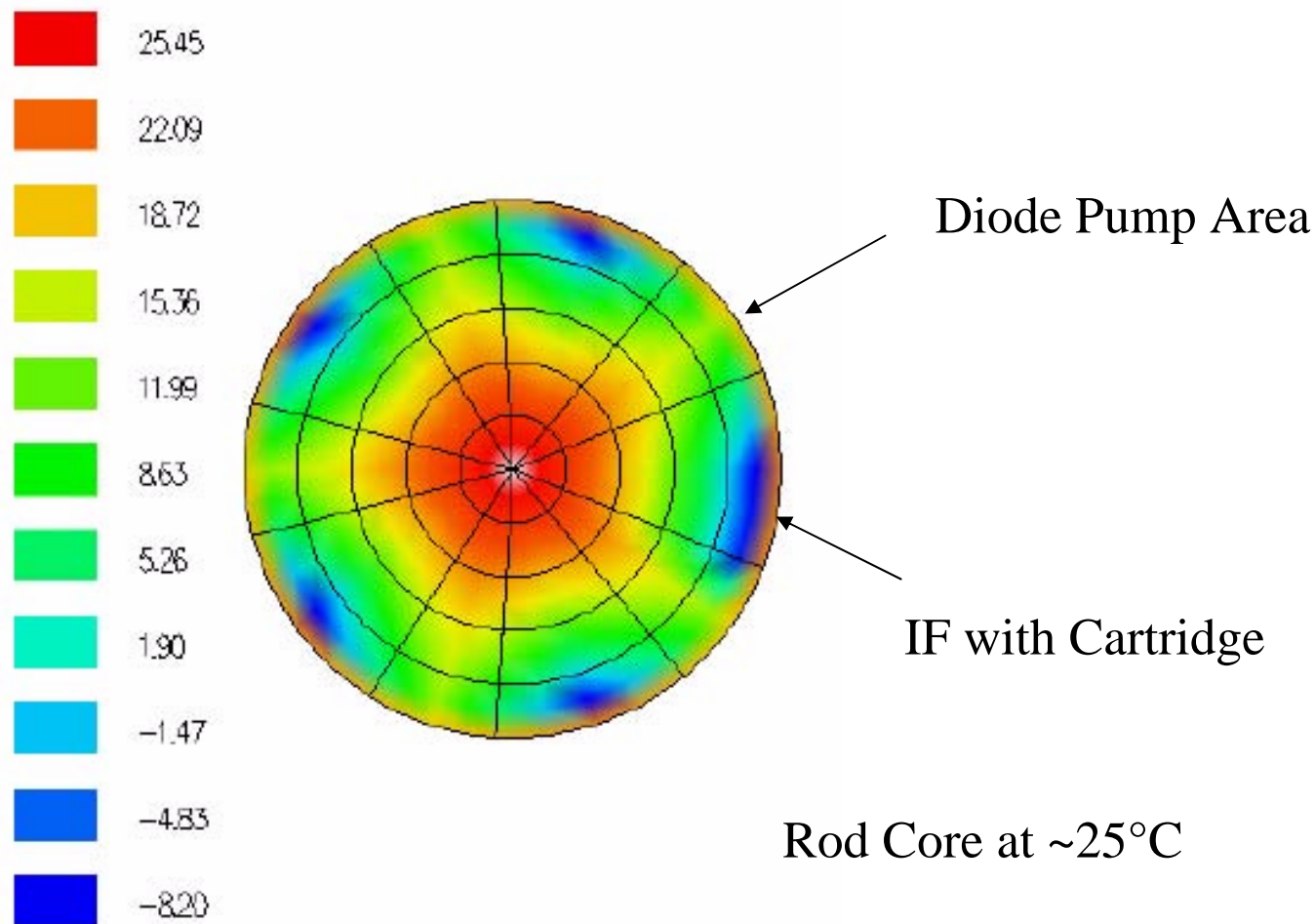
Laser Amplifier Thermal Map

Set Heat Pipe at -56°C to achieve Rod core at 25°C



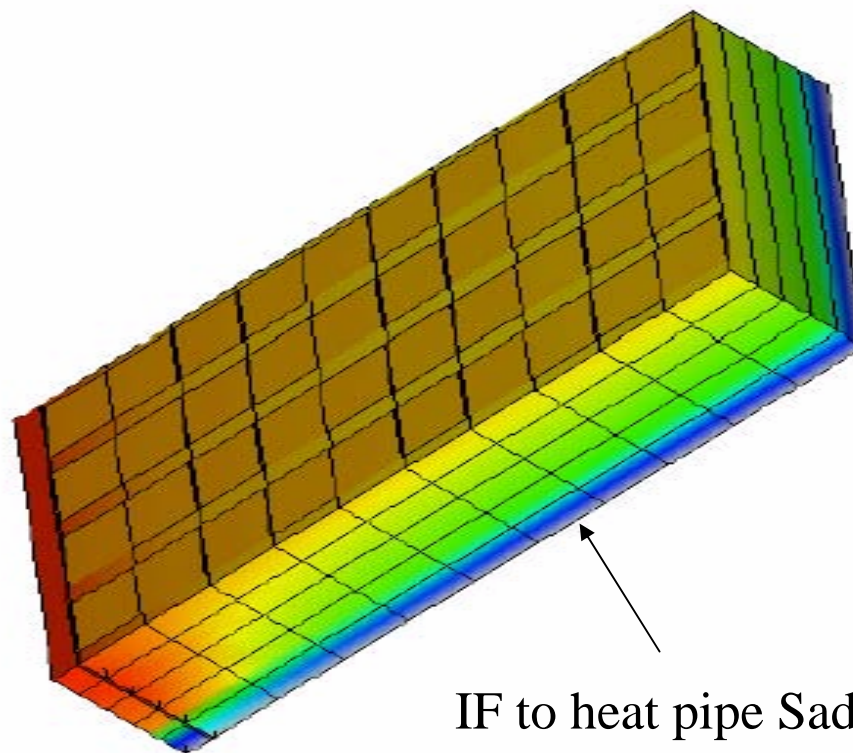
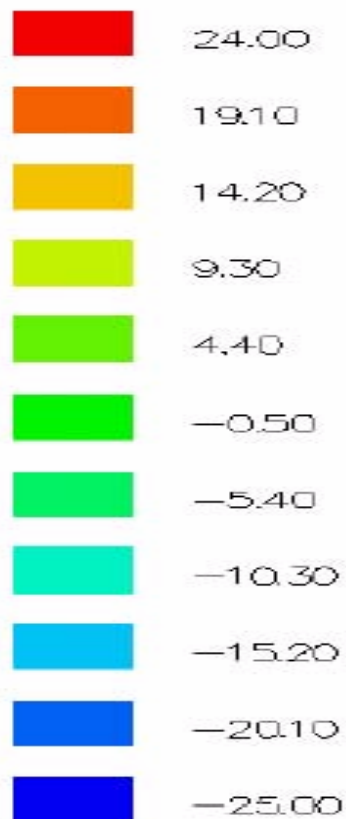


Laser Rod Thermal Map





Diode Thermal Map



IF to heat pipe Saddle

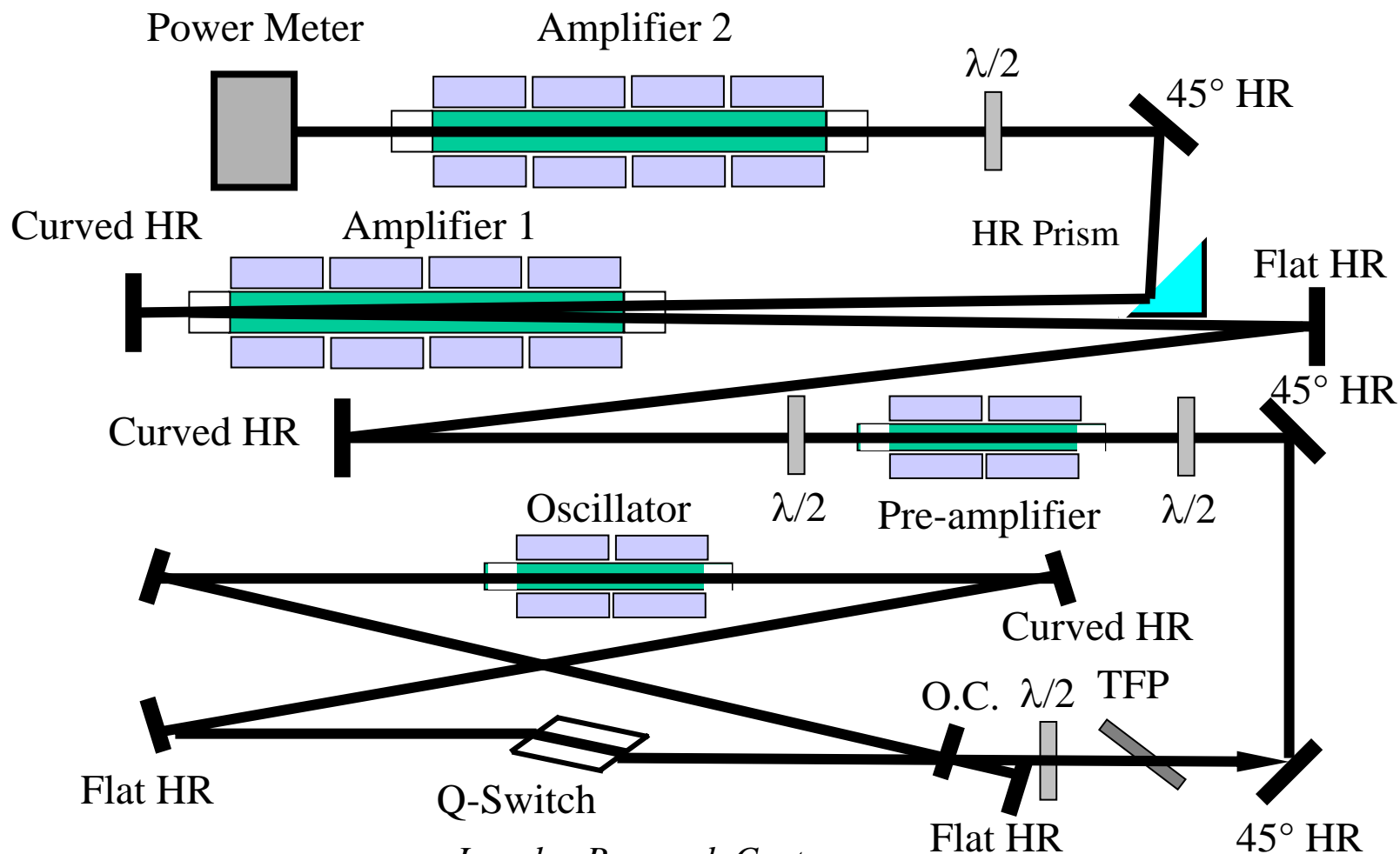


Thermal Analysis Results

- The target temperature for the rod center is 25°C, required setting heat pipe at -56°C. The rod I/F area with cartridge is at -8°C and absorbing diode heat is at 14°C
- The gradient at I/F between rod and cartridge is 29°C, the biggest gradient at pump head design
- The gradient at I/F between cartridge and heat pipe saddle is 7°C
- There are 2 viable material options for the laser amplifier head: copper and Thermokon 83. Thermokon 83 was initially chosen in the oscillator design but copper is recommended for its higher thermal conductivity.
- The rod cartridge and the heat pipe saddle should be fabricated from one piece of copper to significantly reduce the thermal gradients between the rod core and the heat pipe.



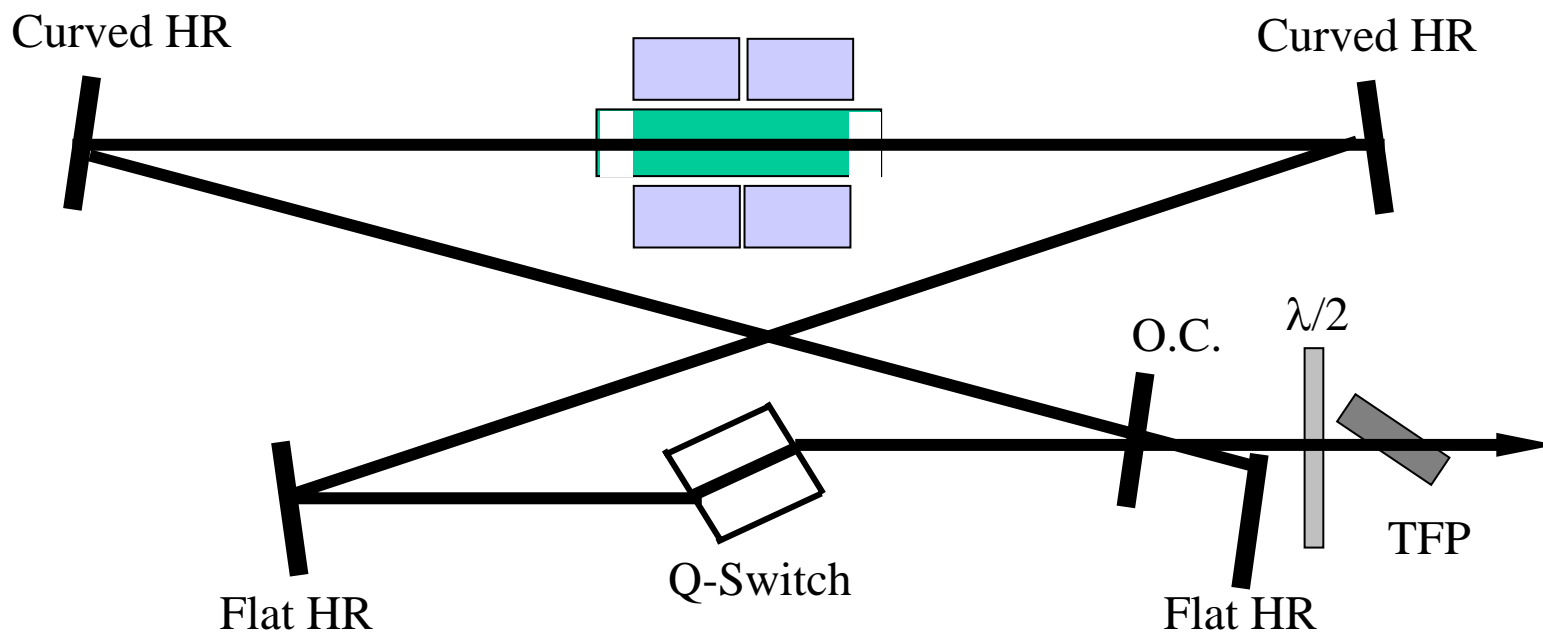
New Experimental Diagram





Laser Oscillator Ring Cavity

(Four high reflectors)





Cavity Mode Simulation

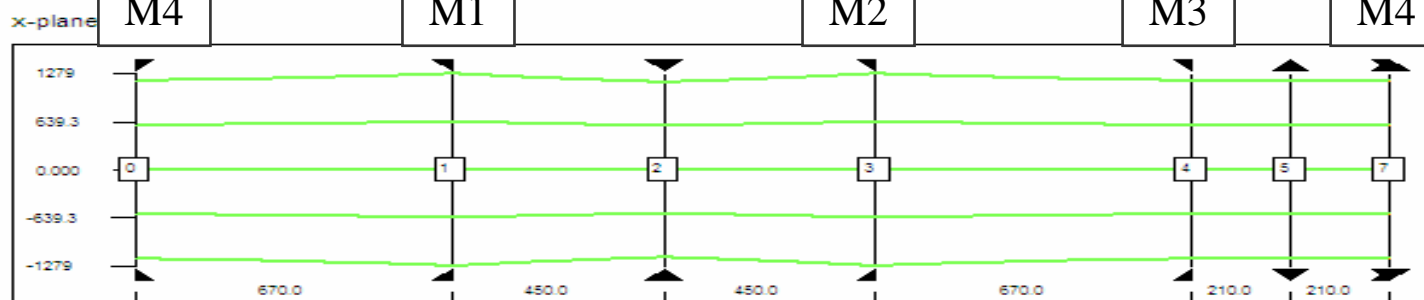
(Ring Cavity with two curved high reflectors)

File: C:\Documents and Settings\Sam Chen\Desktop\Ring Cavity Design\RingCavity.lcd

8/26/2004

RingCavity_3rdLaser

Wavelength = 5 [μm]



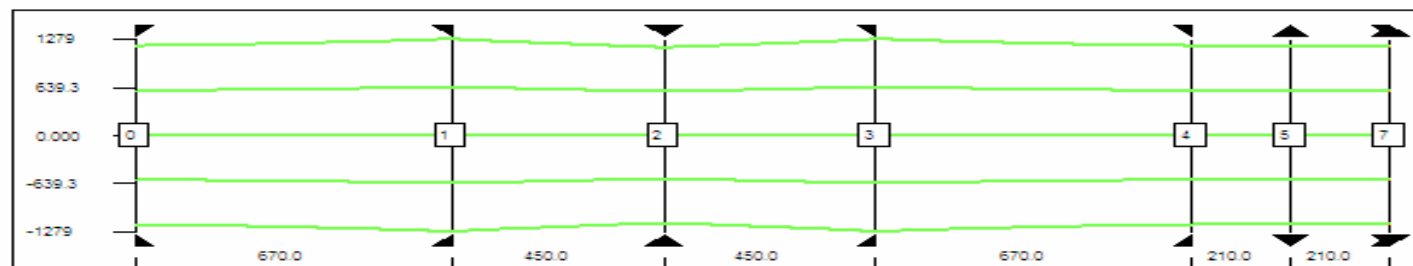
X-axis

size (x-plane) = 1276.4
size (x-plane) = 1163.9

Laser
head

Q-switch

y-plane mode



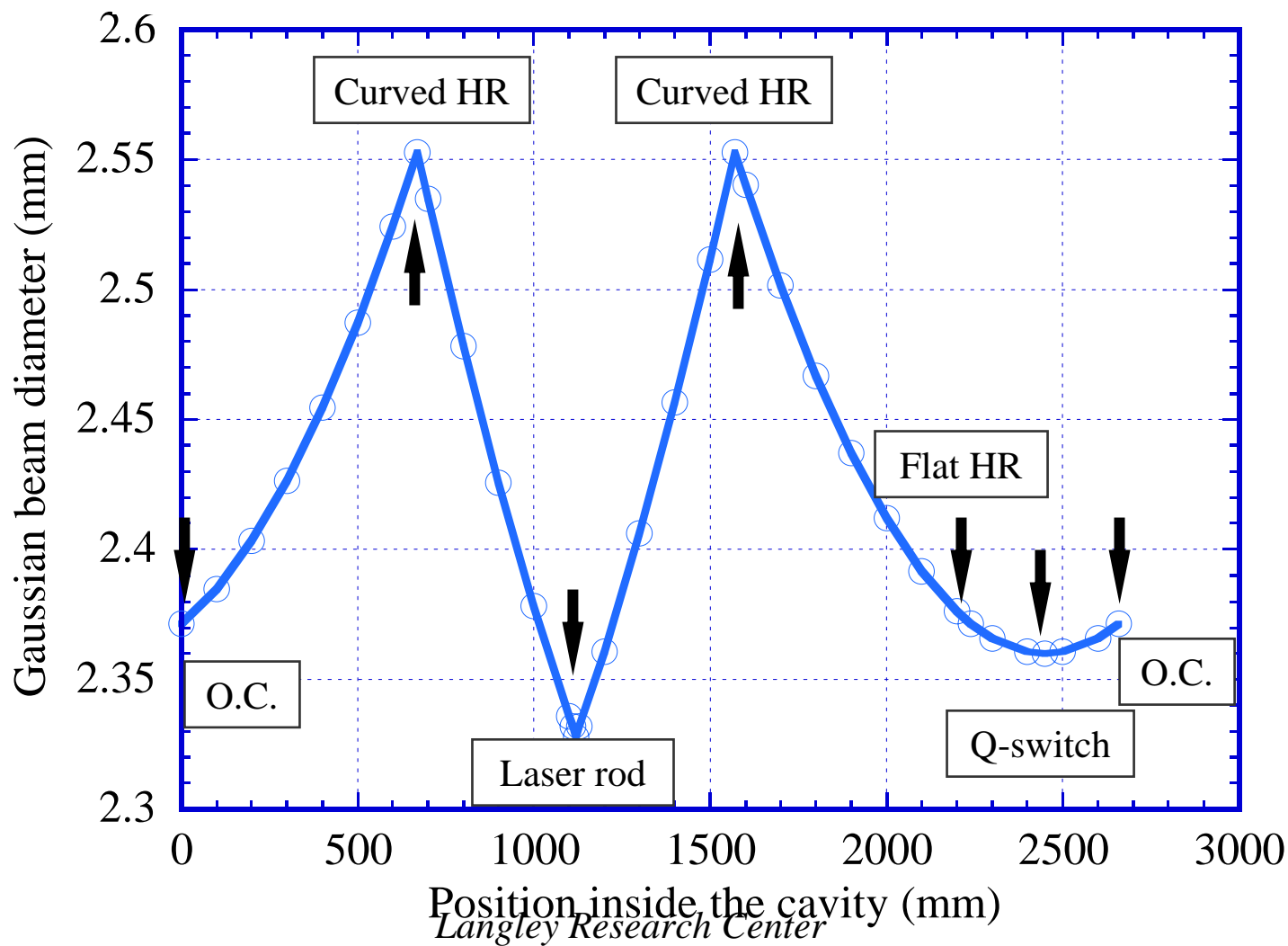
Y-axis

size (y-plane) = 1278.6
size (y-plane) = 1166.1



Cavity Mode Simulation

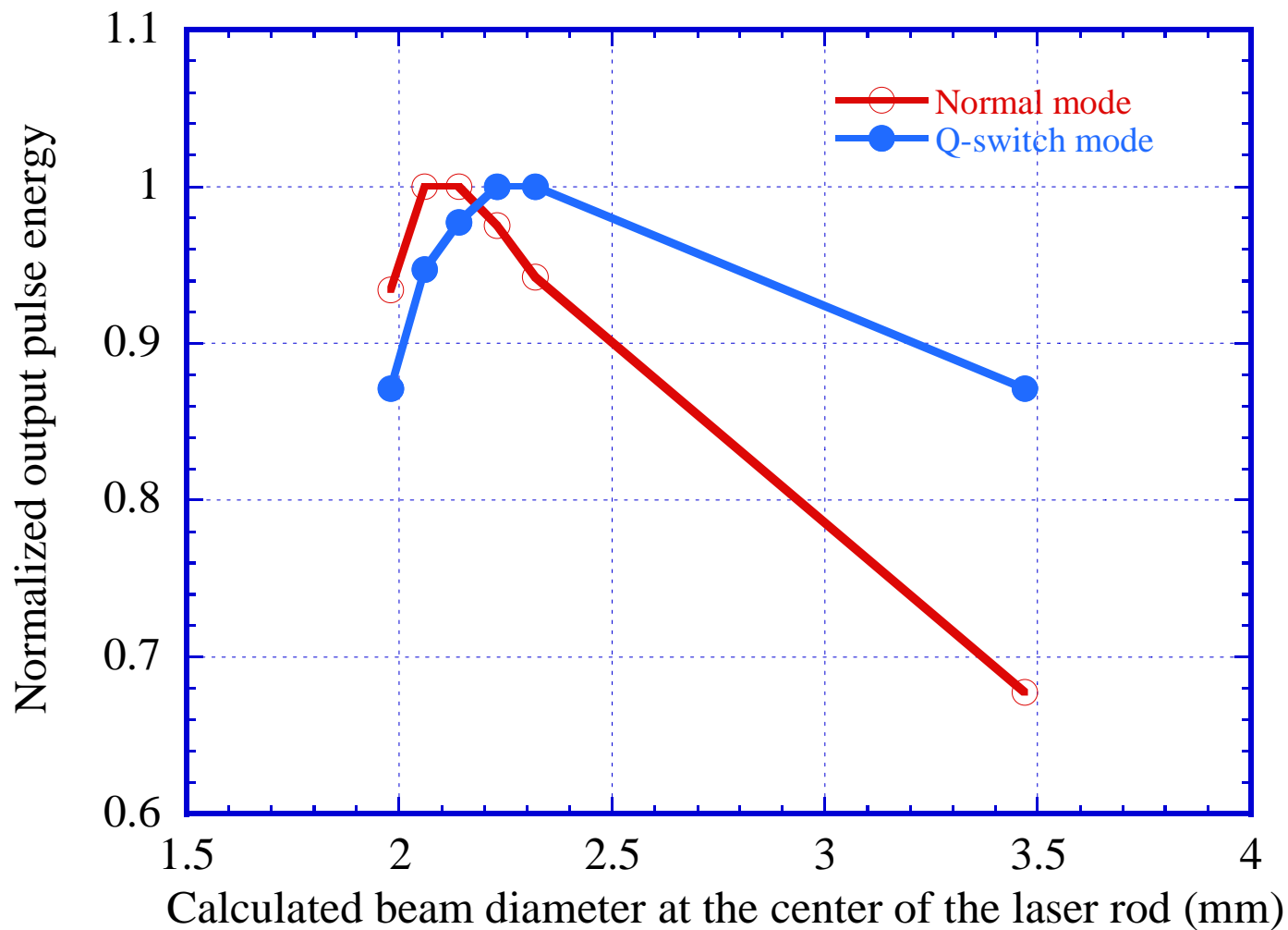
(Gaussian beam size inside the cavity)





Resonant Cavity Experiment

(Output pulse energy ~ Gaussian beam size)



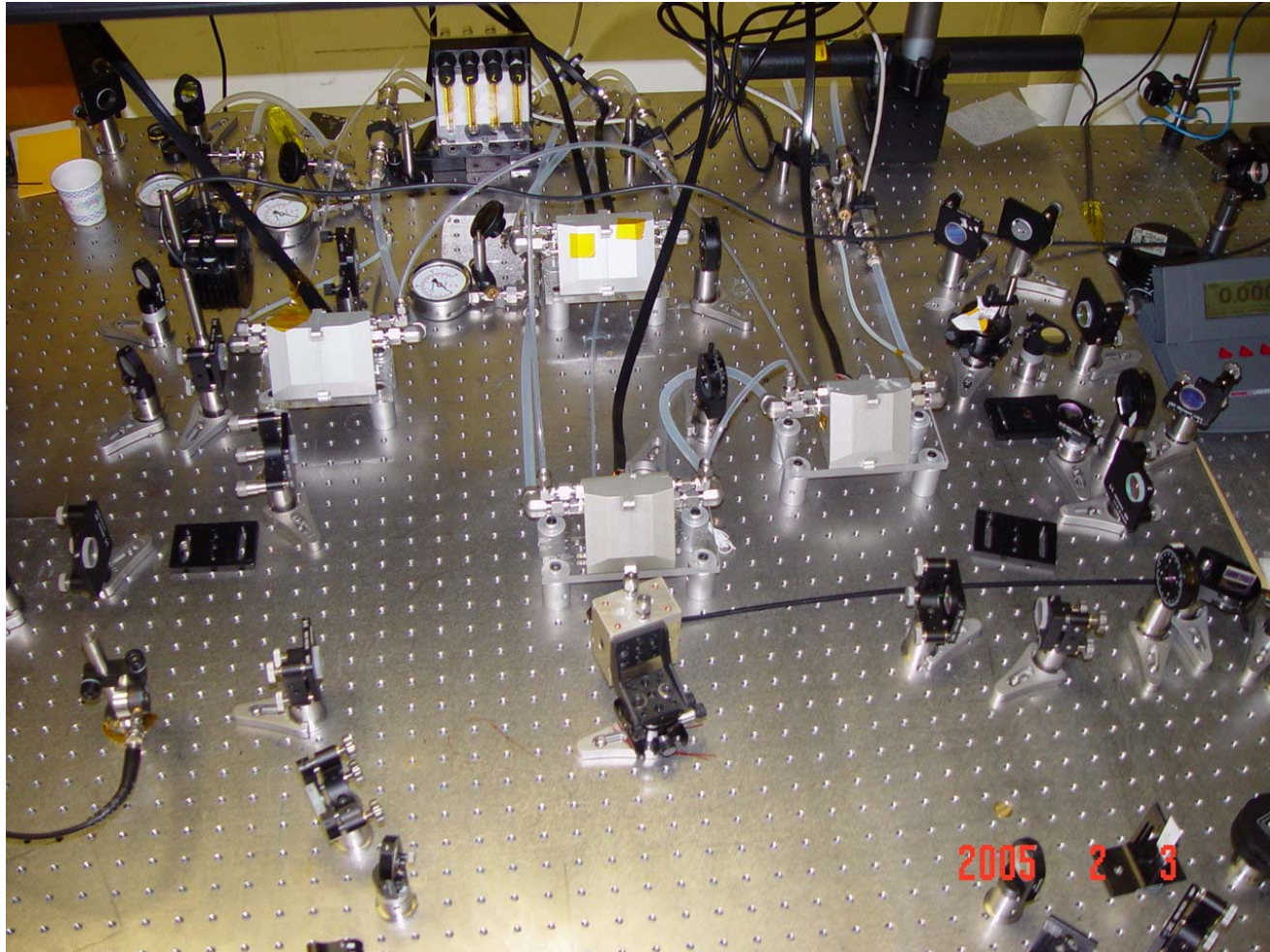


Laser Oscillator Performance

Repetition Rate Frequency (Hz)	Maximum Pumping Pulse Energy (J)	Maximum Total Pulse Energy (mJ)	Thresholds (J)	Slope Efficiency (%)
Normal Mode				
2	3.3	280	2.2	25
10	3.5	290	2.4	26
Single Pulse Q-switch Mode				
2	3.3	156	2.2	14
10	3.5	128	2.4	12
Double Pulse Q-switch Mode				
2	3.3	220	2.2	20
10	3.5	204	2.4	19



New Experimental Setup

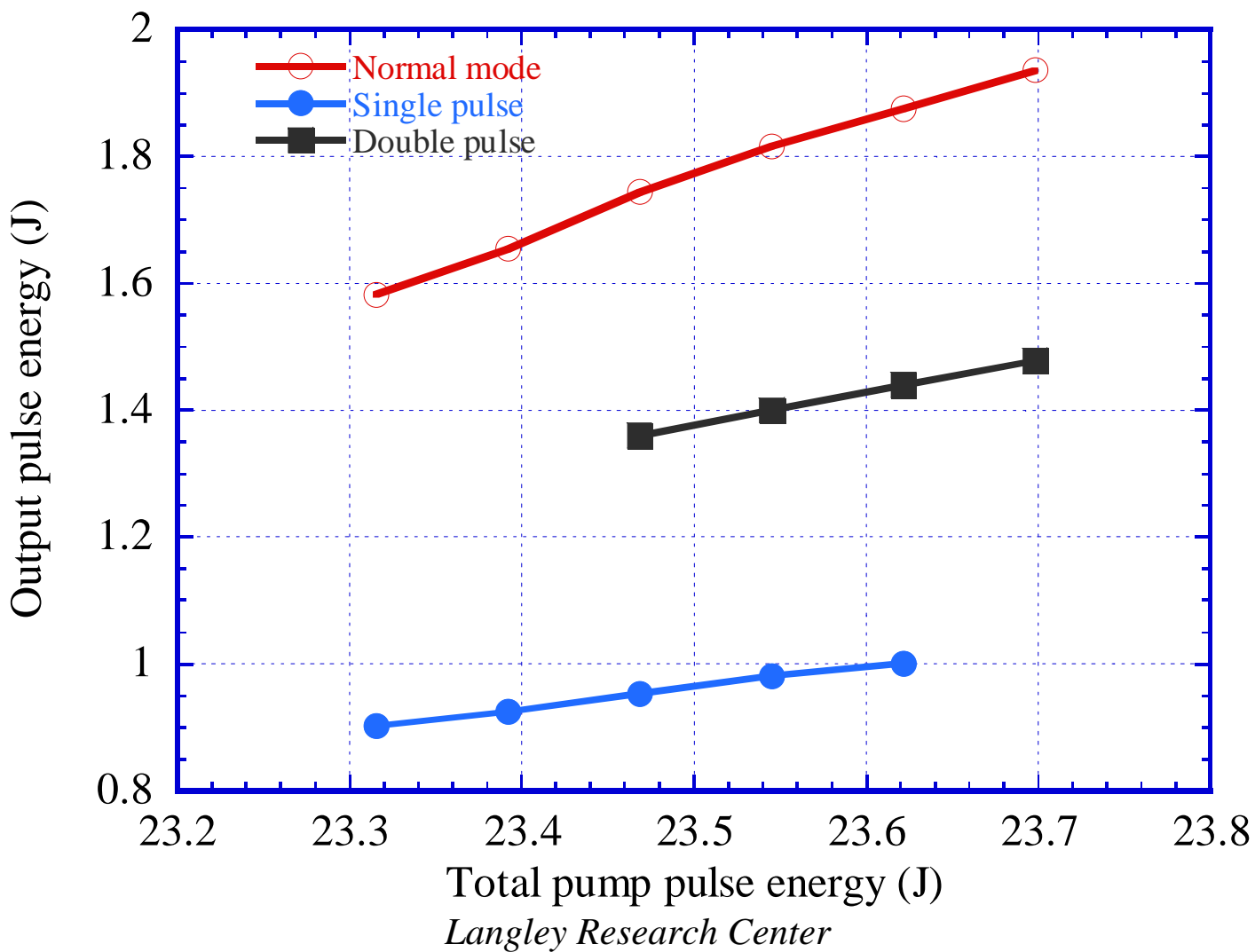


27, June 2005

Langley Research Center



New Experimental Results





1 J single pulse energy

- A diode-laser-side-pumped 2 μm Ho:Tm:LuLF laser oscillator and amplifiers (MOPA) have been developed

Experimental Results

Output energy	1.92 J(NM)	1.0 J(SP)	1.5 J (DP)
Optical efficiency	8.2 %	4.2 %	6.3 %



Fiber pumped Ho Laser

Task Lead : Jirong Yu, NASA Langley Research Center

Objective

- Develop and demonstrate an efficient Tm fiber laser pumped Ho laser
- Address major laser development issues:
 - efficiency
 - energy
 - beam quality
 - thermal management
 - optical and thermal damage

Fiber pumped Ho laser



Approach

- Characterize commercial available Tm fiber laser
- Enhance pump efficiency by adopting end-pump technique.
- Evaluate heat effect on the performance of the laser, and improve the thermal management

Co-I's/Partners

IPG Photonics, Science and Technology Corp. SAIC,

Key Milestones

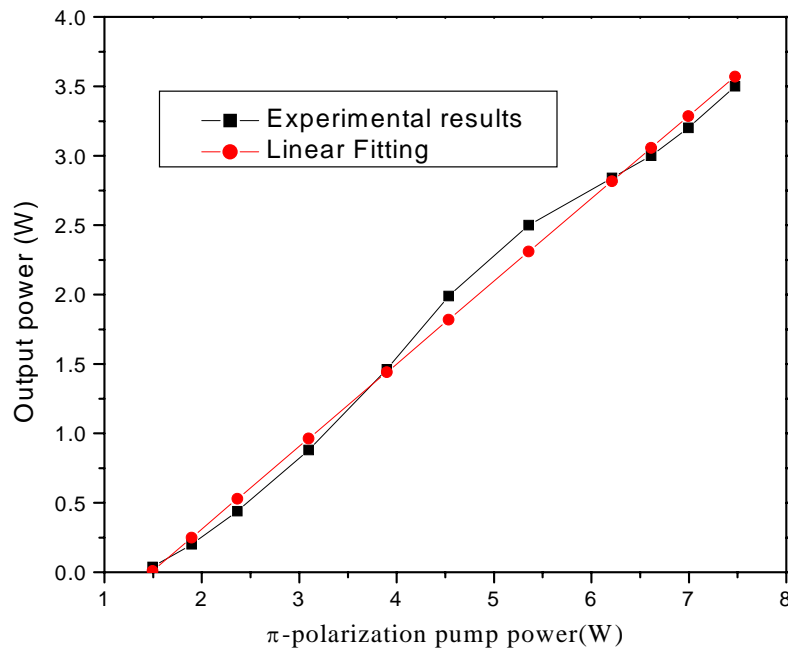
- Develop a model to simulate an end-pumped Ho laser. (3/05)
- Demonstrate a directly pumped CW Ho laser with optical efficiency ~25%.

TRL_{in} = 3



Performances

Slope Efficiency:	58.1%
O-O Efficiency:	47%
Threshold:	1.48 W
Reflection of OC:	58%
Crystal temperature:	-65°C
Pump Beam Waist:	~0.39mm
Ho:YLF Doping:	0.5%
Crystal length:	40mm
Incident pump power:	7.5W
Leakage power	~1W
Output power	~3.5W





Conclusions

- We have demonstrated a diode-pumped, totally conductive cooled, Q-Switched, 2-micron oscillator, which enhanced the technical readiness level of the instrument for space qualification.
- A totally conductively cooled amplifier has been analyzed and designed. Fabrication is in progress.
- We have successfully demonstrated, for the first time, a high energy 2-micron laser that breaks one Joule per pulse barrier.